

Development of Compact Ultra Wideband Antennas

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Abstract—Ultra wideband (UWB) technologies have been proposed and validated for potential high data rate communication systems. In this paper we present some recent works in our group, namely the Research Institute of Electronic Science and Technology (RIEST), University of Electronic Science and Technology of China (UESTC). The development is mainly focused on the miniature and broad band capability, as well as some special requirements, for instance, band-notched characteristics and diversity performance for multi-input multi-output (MIMO). Four compact printed broad band antennas are discussed in total, including an ACS-fed UWB and Bluetooth antenna, an UWB microstrip antenna with dual band notched characteristics and a high-isolation orthogonal diversity UWB and Bluetooth antenna for MIMO applications. At last, a MIMO UWB antenna with a rejected band is proposed.

Index terms: Ultra wideband (UWB) antennas, microstrip antennas, multiple-input multiple-output (MIMO), pattern diversity, band-notched

I. INTRODUCTION

The need of high data rate wireless communications has motivated a lot of advanced technologies and standards in the past decades, not only for wireless local area networks (WLAN) [1], but also long distance data transfer [2]. Among them, ultra wideband (UWB) due to its broad band characteristics, offers very high data rate over 1 Gb/s [3]. The Federal Communication Commissions (FCC) in the United States has announced a frequency bandwidth from 3.1 – 10.6 GHz for commercial use of UWB in 2002 [4], as well as similar standards in Asia [5] and 6.0 – 8.5 GHz in Europe [6].

No matter what the center frequency and bandwidth different standards share, UWB technologies have many potential applications as the next-generation of mobile communications (cell phones), wireless personal area network (WPAN) [7], geological investigation [8] and life detection (through-wall and ground penetrating radar) [9], etc.

A typical UWB system consists of one or multiple transmitters and receivers. At least a source circuit including filtering and amplifying components is made to get RF signals. It is not easy to generate and transmit such broad band signals in the frequency domain. However, a non-sinusoidal transient signal is a good way to get ultra wideband spectrum, as known from the Fast Fourier Transform (FFT), where the bandwidth of the signal is related with the pulse width or rise time. Usually a very fast

switch such as avalanche transistor and step recovery diode is used to achieve sub-nano-sec pulse, which is adequate for a short range transmission. For a receiver, since the impulse wave is carrier free, a mixer is not necessary. This means that the received RF signal is directly amplified, and the data are saved by an A/D sampling module, as depicted in Fig. 1. Each of the transceivers has a pair of transmitting/receiving antennas or array to ensure the energy is propagated efficiently as required. Meanwhile, it is possible to set up an antenna array, not only to improve the gain property, but also to enable beam forming, by adjusting the time delay of each unit [10].

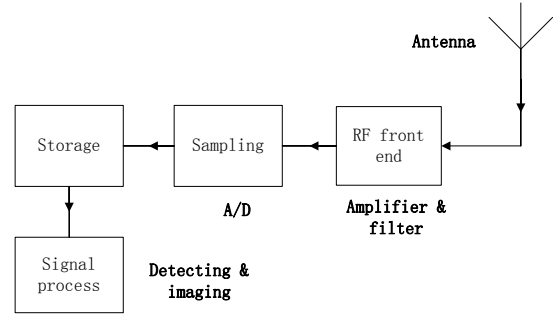


Fig. 1 sketch of a typical UWB receiver

In this paper, we introduce some of the typical UWB antennas that have been developed in the Research Institute of Electronic Science and Technology (RIEST), University of Electronic Science and Technology of China. Besides mentioning some basic ideas and requirements of UWB antennas, the following paper is organized as follows. In section II, two very compact printed UWB antennas are presented. First, we introduce an ACS (asymmetric coplanar strip)-fed antenna, printed on a $32.5 \times 10 \text{ mm}^2$ CPW (coplanar waveguides) circuit board. It has two bandwidths of 0.16 GHz (2.35-2.51 GHz), 8.8 GHz (2.87-11.67 GHz), which meets the requirement of both Bluetooth and UWB standards. Secondly a dual band notched UWB microstrip antenna is proposed, which has been a very popular topic during the past years. With a simple parachute-like patch, as well as a U-shape slot on the patch and an L-shape slot on the ground, the antenna area has been greatly reduced to $27 \times 20 \text{ mm}^2$, with the band of 2.8-11.09 GHz excluding 3.06-3.83, and 5.05-5.96 GHz. In section III, two compact pattern diversity antennas for multiple-input multiple-output (MIMO) applications are presented. The first one is a $48 \times 48 \text{ mm}^2$ UWB and Bluetooth CPW planar antenna, which consists of two staircase-shaped radiators with double fork-like stubs.

This diversity antenna also works for UWB and Bluetooth, with greatly enhanced isolation characteristics. Finally we give a UWB MIMO antenna with band rejection properties, which operates orthogonal radiation patterns from 2.5 to 12 GHz, with a notched band of 5.1 to 6 GHz. Besides, it has a compact size of over 50% less area than previously reported ones.

II. COMPACT UWB ANTENNAS

As important constituents of typical transceivers, antennas for commercial UWB applications are required to feature at least the following properties: 1) very broad band (at least covering 3.1~10.6 GHz, or with multiple bands); 2) compact; 3) omni-directional (360°); 4) flat gain; 5) low cost and fabrication tolerance. Taking account these requirements, we prefer to choose microstrip and coplanar waveguides (CPW) antennas, with the widely used FR4 printed board as the substrate. The typical relative dielectric constant is treated as 4.4, and the loss tangent is 0.02, where the fabrication error is within 0.1mm with a minimum line width lower than 0.2 mm, which is quite affordable. Efficient ways to realize broad band characteristics with antenna compactness, or achieve miniaturization, are to twist the radiating patches to extend the current path and generate multiple resonant frequencies.

A. Compact CPW ACS-fed UWB and Bluetooth antenna

Several compact antenna designs have been proposed to achieve broad band capabilities, as well as the integration of UWB with other wireless narrow bands such as Bluetooth, GSM, and GPS Bands, which are close to 3.1-10.6 GHz. For instance, an electromagnetically coupled UWB plate antenna [11], a small quasi-self-complementary UWB antenna [12], a small ground-independent planar UWB antenna [13-14], dipole antenna with enhanced impedance and gain [15], a UWB monopole antenna with a narrow L-shaped strip [16], a fork-shaped monopole antenna [17], inverted-C shape ASY antenna [18], slot antennas [19-21], and many other milestone works of miniaturization [22-25]. However, reported antennas usually have complex structures, or their overall dimensions still require to be reduced. This is what has motivated the work in the following sections..

In this section we give an example of an ACS-fed UWB monopole antenna. The design of this antenna is shown in Fig. 2. The CPW-fed structure is printed on a $32.5 \times 10 \times 1.6$ mm³ FR4 substrate. Antenna 1 in Fig. 3 is the original ACS-fed UWB monopole antenna, which consists of a modified ACS-fed structure and a staircase-shaped patch. The ACS-fed structure is modified by etching one 2×0.5 mm² rectangular patch on the ground plane. It makes the port to match the 50- Ω characteristic impedance. Furthermore, the proposed antenna used a staircase-shaped radiating patch to obtain better impedance matching. As illustrated in Fig. 3, the simulated -10 dB impedance bandwidth of antenna 1 is 7.74 GHz (3.01-10.75 GHz), which can be used for the UWB band. Then a snake-shaped slot is embedded in the staircase-shaped patch (antenna 2) to generate the resonant mode at about 2.45 GHz. Antenna 2 has impedance bandwidths of 2.37-2.53 GHz and 3.22-10.82 GHz, which

can be used for the UWB band and Bluetooth band. Additionally, the length of the snake-shaped slot is found to be nearly a quarter of the dielectric wavelength calculated at the desired resonant frequency. It can be seen that introduce the snake-shaped slot makes the performance of UWB band nearly not influenced. Therefore, the ACS-fed UWB monopole antenna with extra Bluetooth band is obtained. The detailed dimensions are in Fig.2 as follows: $W=10$ mm, $L=32.5$ mm, $l_1=6.5$ mm, $l_2=2$ mm, $l_3=5$ mm, $l_4=8.5$ mm, $l_5=3.9$ mm, $l_6=6.2$ mm, $w_1=0.5$ mm, $w_2=3$ mm, $w_3=8$ mm, $w_4=2$ mm, $w_5=3$ mm, $w_6=1.3$ mm, $w_f=2$ mm, $g=0.1$ mm.

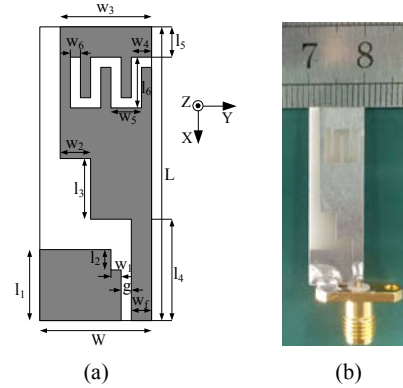


Fig. 2 Sketch and photograph of the proposed antenna. (a) sketch, (b) photo of fabrication

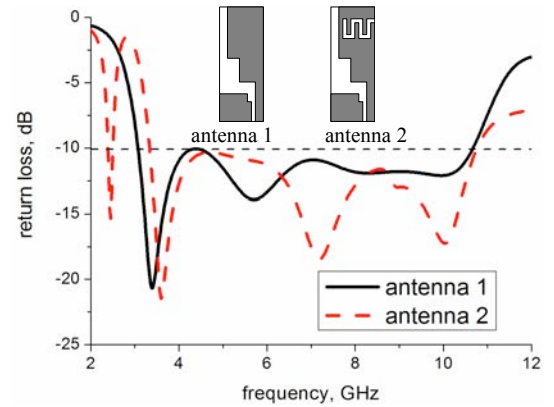


Fig. 3 Simulated return losses of the antennas

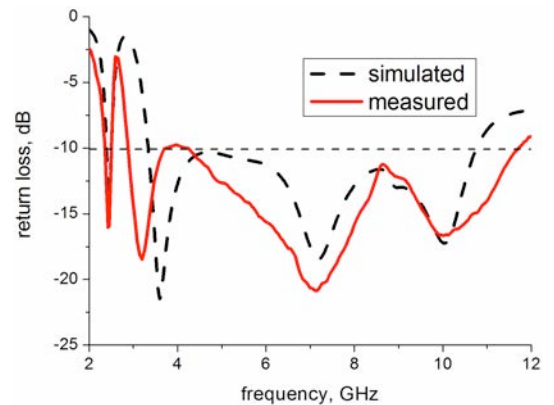


Fig. 4 Simulated and measured return losses against frequency

The comparison of simulated and measured return losses of this antenna is given in Fig. 4. Measured impedance bandwidths are 0.16 GHz (2.35-2.51 GHz) and 8.8 GHz (2.87-11.67 GHz), which cover both UWB and Bluetooth requirements. Fig. 5 shows simulated far field radiation

patterns in E-plane (XZ-plane) and H-plane (YZ-plane) at 2.4, 4, 6.5, and 9 GHz, respectively. Nearly omni-directional patterns are obtained over the desired operating bands. It can be seen that the radiation pattern deteriorates slightly at the higher resonant frequency, and this may be due to the fact that the asymmetric ground plane of the present design is half of the CPW-fed antennas. The simulated peak gains of the proposed antenna across the Bluetooth and UWB bands are depicted in Fig. 6. It can be seen that the peak gains are almost constant in the entire band (2-11 GHz) with variation less than 1.5 dBi. Therefore, the proposed antenna exhibits stable gains across the operating bands, which makes it is suitable for practical applications.

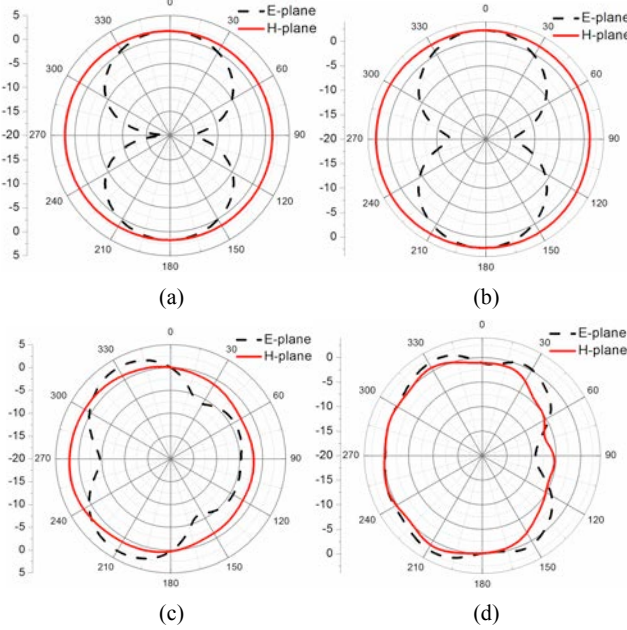


Fig. 5 Radiation patterns of the proposed antenna. (a) 2.4 GHz, (b) 4 GHz, (c) 6.5 GHz, (d) 9 GHz

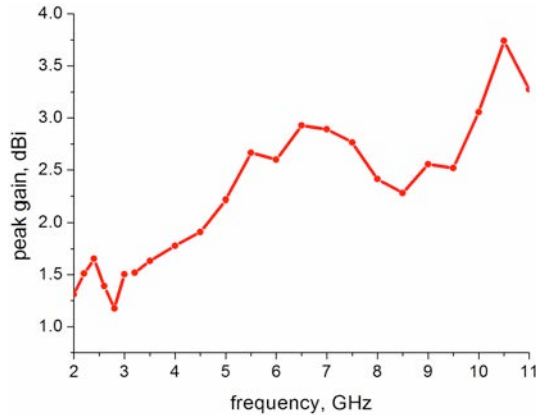


Fig. 6 Peak gains of the proposed antenna

The measured group delays of the proposed antenna for both face-to-face and side-by-side configurations are shown in Fig. 7. In each case, two similar UWB antennas that are placed 30 cm apart are used. As it can be seen, the maximum variation of the group delay for the face-to-face configuration is less than 0.75 ns, while that of the side-by-side case is less than 1 ns. This confirms that the UWB antenna is suitable for UWB communication.

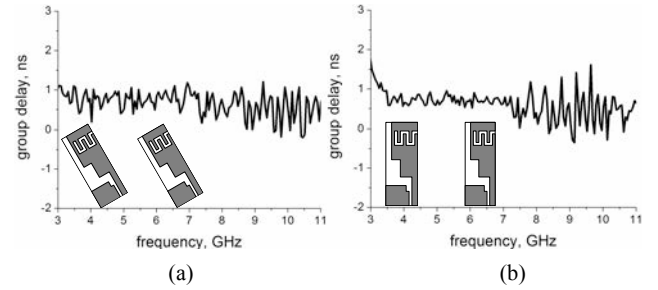
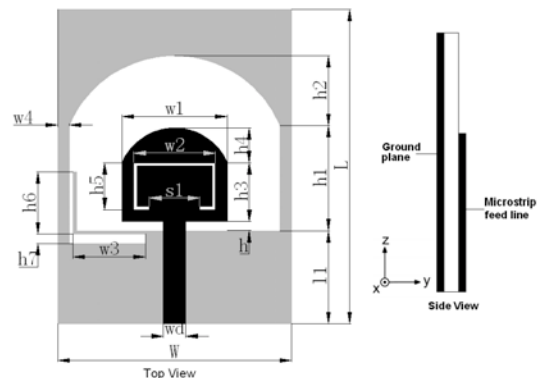


Fig. 7 Measured group delays of the proposed antenna. (a) Face-to-face, (b) Side-by-side

B. Compact UWB antenna with band notched characteristics

Over the UWB working band, there are some other existing narrow band communication systems, such as the 3.4-3.69 GHz band (IEEE 802.16) worldwide interoperability for microwave access (WiMAX), the 5.15-5.825 GHz band (IEEE 802.11a) wireless local area networks (WLAN), which may cause possible electromagnetic interference to the UWB applications. To solve this problem, many significant band-notched techniques have been proposed in UWB antennas, including etching U-shaped slot [26-27], V-shaped slot [28], C-shaped slot [29], S-shaped slot [30], employing a defected ground d structure (DGS) [31], embedding a quarter-wavelength tuning stub in a large slot on the patch [32], adding shorting pins [33-34] or locating compact folded stepped impedance resonators (SIRs) or capacitively loaded loop (CLL) resonators beside the feed line [35-36].

However, reported UWB antennas listed above have sizes varying from $30 \times 46 \text{ mm}^2$ to $26 \times 30 \text{ mm}^2$, with scope for further reduction. Recently, the rapid development of mobile devices and wireless personal area network (WPAN) has motivated research on the miniaturization of UWB antennas, and band-notched ones with compact size have been reported [37-40]. Although the size of the antennas has been obviously cut down from 20-24 mm to 18-29 mm, the performances of band-notched characteristics are sacrificed. For instance, the antennas reported in [37-39] have only single 5-6 GHz band-notched characteristic because of their limited size that cannot support another rejection structure. In [40], the highest voltage standing wave ratio (VSWR) at the notched band is about 4 which implies that over half of the energy is radiated. In this case, it is clearly necessary to study and realize size reduction without performance degradation.



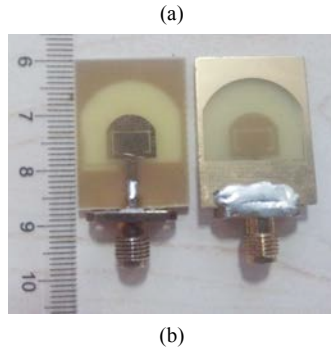


Fig. 8 Geometry of the proposed antenna with (a) top view and (b) fabricated antenna.

Fig. 8 (a) describes the geometry of the proposed antenna. The photograph of the fabricated antenna is shown in Fig. 8 (b). The antenna is fabricated on a low-cost FR-4 substrate with thickness of 1 mm and relative dielectric constant of 4.4. A wide inverted U-shaped slot is cut on the ground plane. The inverted U-shaped radiation patch is fed by a 50 Ω microstrip line. The optimal dimensions of the antenna are given as follows: $W=20$ mm, $w_d=1.9$ mm, $w_1=9$ mm, $w_2=7$ mm, $w_3=6.2$ mm, $w_4=1$ mm, $h=0.8$ mm, $h_1=9$ mm, $h_2=6$ mm, $h_3=5$ mm, $h_4=3$ mm, $h_5=4$ mm, $h_6=5.5$ mm, $h_7=0.8$ mm, $s_1=4.3$ mm, $L=27$ mm, and $l_1=8$ mm.

The first notched band centered at 3.52 GHz is produced by the L-shaped stub extruding from the ground plane. The L-shaped stub acts as a quarter-guide-wavelength parallel open circuit transmission line that shorts the antenna at the relevant frequency. The length of the stub at the center frequency of the notched band can be calculated by (1).

$$L_1 = \frac{c}{4f\sqrt{\frac{\epsilon_r + 1}{2}}} \quad (1)$$

Here c is the speed of the light, ϵ_r is the dielectric constant, and L_1 ($L_1=w_3+h_6$) is the length of the stub. According to (1), the calculated length of the L-shaped stub is 12.9 mm. The practical length of the L-shaped stub is 11.7 mm.

The second notched band centered at 5.57 GHz is obtained by etching a C-shaped slot on the radiation patch. The length of the slot is about $\lambda/2$ of the center frequency of the notched band and can be calculated by (2),

$$L_2 = \frac{c}{2f\sqrt{\frac{\epsilon_r + 1}{2}}} \quad (2)$$

where L_2 ($L_2=2*(w_2+h_5)-s_1$) is the length of the stub. According to (2), the calculated length of the C-shaped stub is 16.4 mm. The practical length of the C-shaped slot is 17.7 mm.

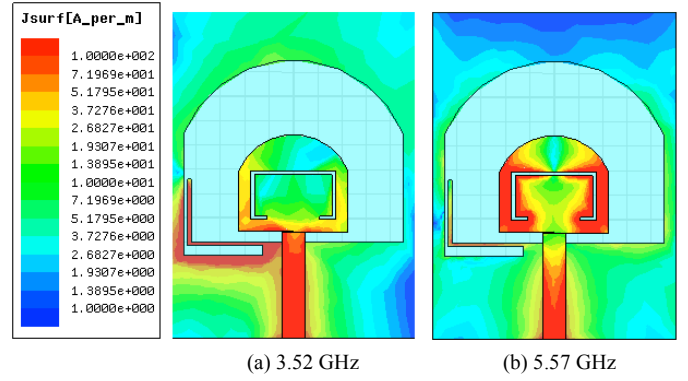


Fig. 9. Simulated current distributions at different notched frequencies.

Fig. 9 shows the simulated current distributions of the designed antenna at the notched frequencies. It is clearly seen that in the first notched band (3.3-3.9 GHz), the current is concentrated around the L-shaped stub. Similarly, the surface current concentration exists near the C-shaped slot in the higher-frequency notch (5.1-6 GHz).

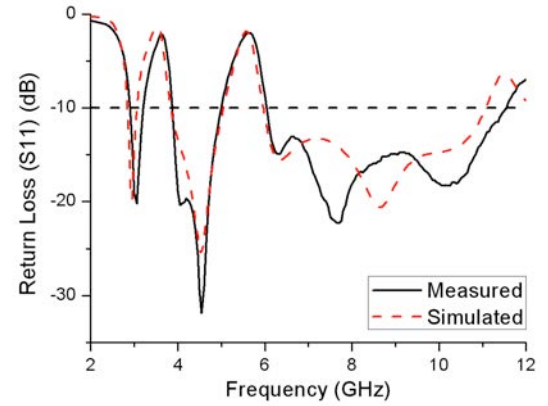
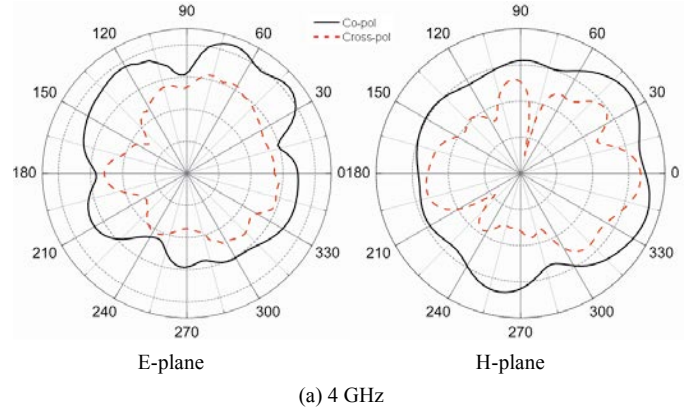


Fig.10 Measured and simulated S-parameter results of the dual band-notched antenna.



(a) 4 GHz

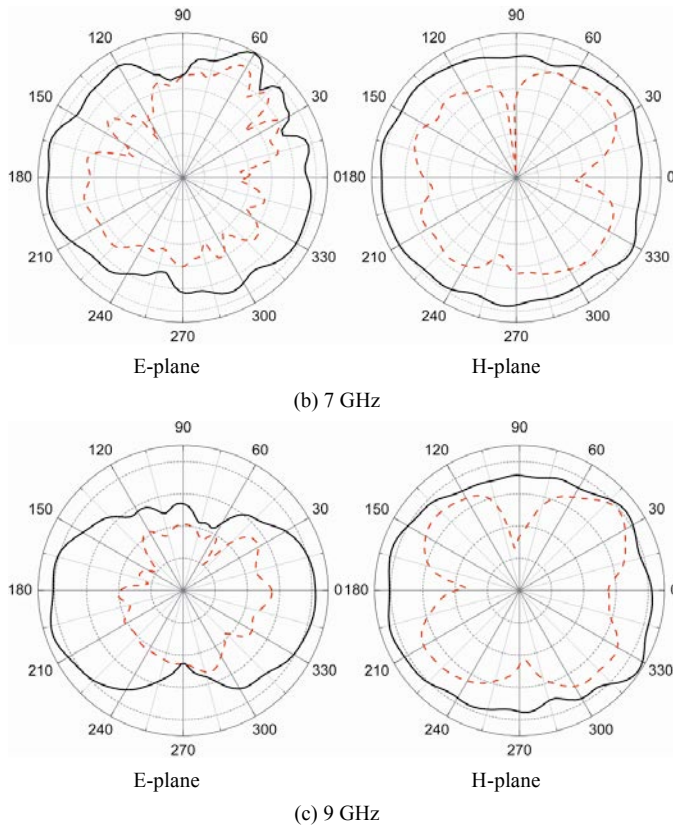


Fig. 11 Measured radiation patterns of the dual band-notched antenna at the frequencies at (a) 4 GHz, (b) 7 GHz, and (c) 9 GHz.

This antenna is designed and optimized with Ansoft HFSS V12. The S-parameter (return loss) of the proposed antenna is measured by the Agilent E8363B vector network analyzer. For comparison, measured and simulated S-parameter curves of the dual band-notched antenna are given in Fig. 10. It can be seen that the simulated impedance bandwidth for $S_{11} \leq -10$ dB is 2.8-11.09 GHz except for 3.06-3.83, and 5.05-5.96 GHz. The center frequencies of the two notched-bands are 3.52 and 5.57 GHz, and the maximum values of the S_{11} are -1.34 and -1.82 dB. At the same time, the measured impedance bandwidth for $S_{11} \leq -10$ dB is 2.89-11.52 GHz, except for 3.18-3.85, and 5.0 -6.0 GHz. The center frequencies of the two notched-bands are 3.6 and 5.65 GHz, and the maximum values of the S_{11} are -2.1 and -1.9 dB. Good agreement between the simulated and measured results is observed. The small discrepancy between the measured and simulated results is caused by the introducing of the SMA connector and fabrication tolerance. E-plane (YOZ) and H-plane (XOZ) radiation patterns are measured with SATIMO StarLab, where related 4, 7, and 9 GHz ones are normalized and plotted in Fig. 11(a), (b), and (c). Nearly omni-directional radiation patterns are obtained in the H-plane over the whole UWB frequency range. In addition, the measured gain of the antenna with and without rejected bands, from 3 to 11 GHz is shown in Fig. 12. In the working band, the dual band-notched antenna has a stable gain with a variation of less than 3 dB. It can be also observed that there are two sharp decreasing trends, which proves two bands are distinctly notched through pass band. The reason of small frequency shift in the second notched band is due to the error of radiation pattern measurement.

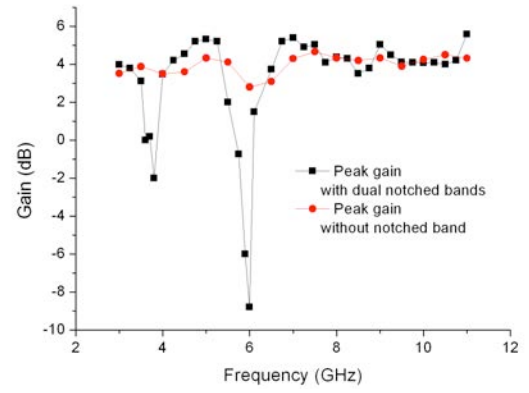


Fig. 12 Measured gain of the antenna with and without notched band

III. UWB MIMO ANTENNAS

Due to the potential interference to similar frequency devices, the emission power spectrum that FCC permitted is only -41.3dBm/MHz [4]. Considering this level and the challenge of multi-path, this transmission distance is typically very short. Multiple-input multiple-output (MIMO) technology has been proposed to solve this problem [41]. Several types of diversity, such as space, pattern and polarization diversity have been used in MIMO standards. Among them, using multiple directional beams to obtain independent signals, pattern diversity techniques are very applicable in mobile terminals due to their easy designs and fabrications. Different radiation patterns are used to improve channel fading and the transmission quality of the mobile terminals, e.g., orthogonal radiation patterns and symmetrical radiation patterns [42]. Moreover, it is an efficient way to reduce antenna size.

A. Compact UWB diversity antennas with high isolations

High isolation and wide band characteristics are required for UWB diversity antennas; this has been studied recently, including etching a ring slot in the ground plane [43] and [44], inserting stubs between the two radiating elements [45], extending a tree-like structure on the ground plane [46]. However, the size of reported antennas is still as large as $80 \times 80 \text{ mm}^2$. We believe this can be reduced, and this has motivated the following work.

In this part we propose a $48 \times 48 \text{ mm}^2$ UWB and Bluetooth planar antenna, which is printed on an FR4 substrate. This antenna consists of two staircase-shaped radiators, which are fed by coplanar waveguide, respectively. The excitation ports are modified by the staircase structures which make them match $50\text{-}\Omega$ impedance. The ground plane is shaped with a quarter circular ring and two fork-like stubs, where this can efficiently enhance wideband isolation characteristics. The geometry of the proposed antenna is shown in Fig. 13. All units are in mm.

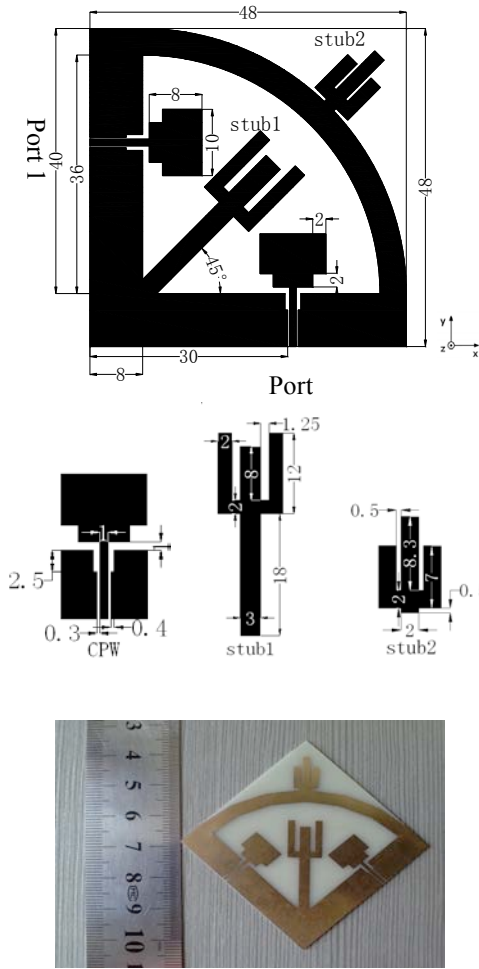


Fig. 13 Configuration and parameters of proposed antenna.

The fork-like stub is included to control the variations of the S-parameters with increasing the number of the stubs. As a quarter-wavelength reflector, the stubs reduce the wideband mutual coupling through separating the radiation patterns of the two radiators [47]. The length of the stubs l can be estimated by (3),

$$l = \frac{c}{4f \cdot \sqrt{\epsilon_r + 1}} \quad (3)$$

where f is the frequency of resonance; ϵ_r is the dielectric constant; c is speed of the light. Stub 1 obtains two different lengths of 12mm and 8mm ($\lambda/4$ of 4GHz and 6GHz). Stub 2 also has two different lengths of 8.3mm and 7mm ($\lambda/4$ of 5GHz and 7.5GHz).

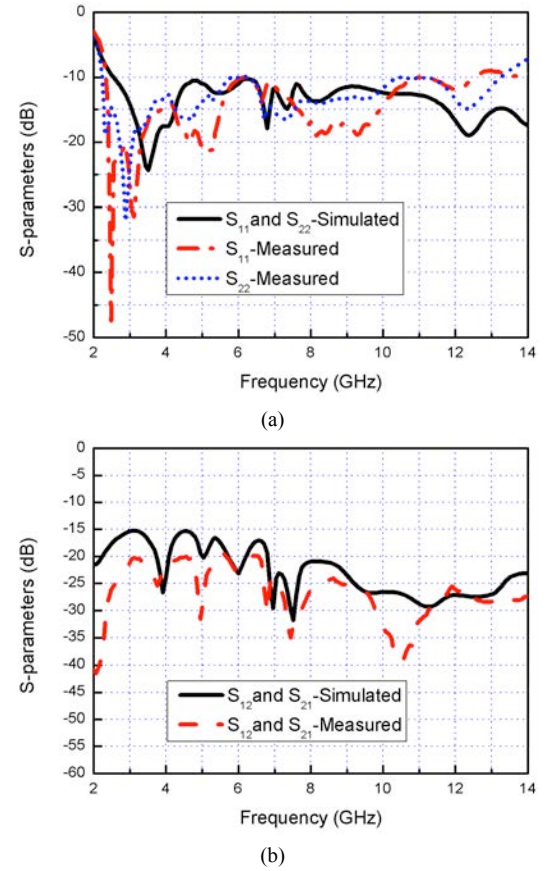


Fig. 14 Measured and simulated S-parameters of the proposed antenna: (a) S11 and S22, (b) S12 and S21.

Fig. 14 shows the simulated and measured S-parameters of the proposed antenna. As indicated in Fig. 14(a), simulated return losses (S_{11} and S_{22}) are identical for both ports due to symmetrical structures, while there are acceptable discrepancies of measurements. These are mainly led by the difference of soldering connectors. According to the measured results, the impedance bandwidth is from 2.3 to 12.5 GHz which can cover Bluetooth, WLAN, WiMAX, UWB. As observed in Fig. 14(b), the isolation of the two ports is more than 20 dB according to the measurement. These results indicate that this antenna is suitable for diversity systems.

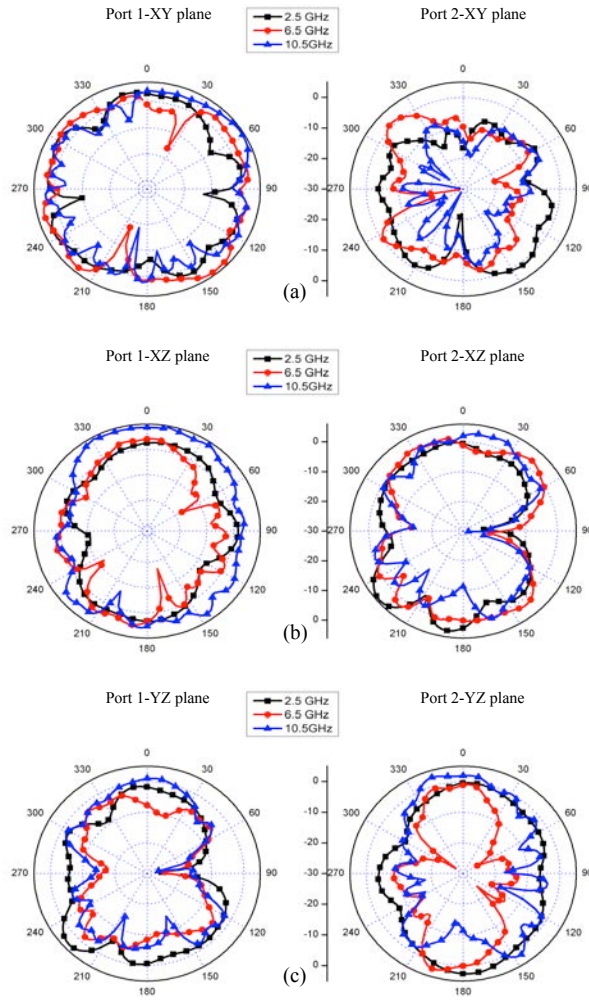


Fig. 15 Measured radiation pattern of the proposed antenna at 2.5, 6.5, 10.5 GHz: (a) XY plane; (b) XZ plane; (c) YZ plane.

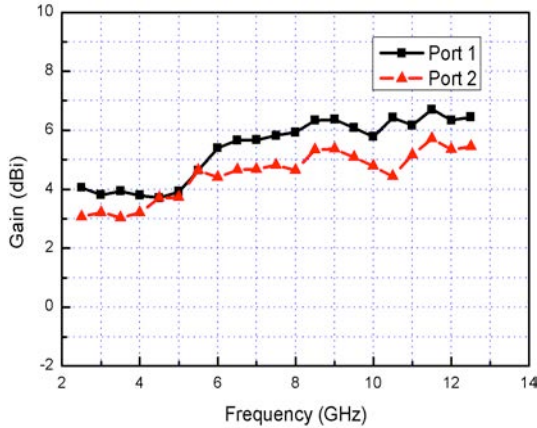


Fig. 16 Measured gain of the proposed antenna.

Fig. 15 shows the radiation patterns of the proposed antenna at 2.5, 6.5, and 10.5 GHz when port 1 is excited, while port 2 is terminated with $50\text{-}\Omega$ load, and vice versa. Owing to the location of the radiators, it is observed that the XY-planes of the port 1 and port 2 exhibit almost 45 degrees symmetry and the XZ-plane (YZ-plane) for the port 1 is similar to the YZ-plane (XZ-plane) of the port 2 which means the patterns of port1 and port2 are almost

rotated 90 degrees. So the antenna can receive vertical polarization waves and horizontal polarization waves at the same time. The antenna peak gain has also been measured and plotted in the Fig. 16. The peak gain increases with operation frequency and the variation of the antenna peak gain is within 3 dB.

B. UWB diversity antenna with band notched characteristics

It is very difficult to simply apply traditional band rejection structures to MIMO/diversity antennas, since this will cause strong mutual coupling between radiating elements. Also, to get high isolation and decoupling characteristics, strongly impacts the band-rejection functions. This becomes more challenging when antennas are being designed compactly, which has rarely been reported. Lately, a printed folded monopole antenna which meets UWB requirement with the WLAN band-rejection was proposed [48]. Although the antenna has favorable bandwidth performance, it has a total size of $55 \times 100 \text{ mm}^2$. The rapid development of portable devices and wireless personal area network (WPAN) has inspired recent research efforts on the miniaturization of UWB components.

In this part, a band-notched UWB pattern diversity antenna is proposed. Two staircase-shaped radiating elements fed by modified coplanar waveguides (CPW) are designed to achieve UWB characteristics and orthogonal radiation patterns. A decoupling rectangular stub is placed at 45° degrees between the two radiators to ensure high isolations. By etching two split-ring resonator (SRR) slots on the respective radiators, very good 5.5 GHz band-notched performance is achieved, with efficient miniaturization of the radiators. Simulated and measured results consistently show that this antenna operates from 2.5 to 12 GHz, with a notched band of 5.1 to 6 GHz. The measurements of the radiation patterns and envelope correlation coefficient (ECC) show that the antenna is suitable for MIMO/diversity systems. Meanwhile, this antenna has a simple structure and a compact size of $48 \times 48 \text{ mm}^2$, which is over 50% less area than previously presented ones for integration in portable devices.

Fig. 17 (a) describes the geometry of the proposed antenna. It is fabricated on a common and low-cost FR4 substrate, with a total size of $48 \text{ mm} \times 48 \text{ mm} \times 0.8 \text{ mm}$, a relative dielectric constant of 4.4, and a loss tangent of 0.02. It consists of two stair-shaped radiating elements, both fed by coplanar waveguides, which obtain more resonant frequencies and achieve UWB characteristics [49]. A $\lambda/4$ circular slot is etched on the antenna and one rectangle stub is extended from the ground plane symmetrically at 45° degrees, to extend the effective current route and enhance the wideband isolation. Each radiator has an etched slot, which provides the band rejection characteristics. The optimized dimensions are derived using Ansoft HFSS V13, shown in Fig. 17(a), all in mm: $w=l=48$, $r=36$, $l_1=8$, $l_2=30$, $l_3=26.5$, $g_1=3$, $h=1$, $h_1=8$, $w_1=10$, $h_2=3$, $w_2=1$, $w_d=1$, $g_2=0.3$, $h_3=4.25$, $h_4=0.6$, $g_3=0.4$, $w_3=5.8$, $w_4=0.8$. A photo of the fabricated antenna is shown in Fig. 17(b).

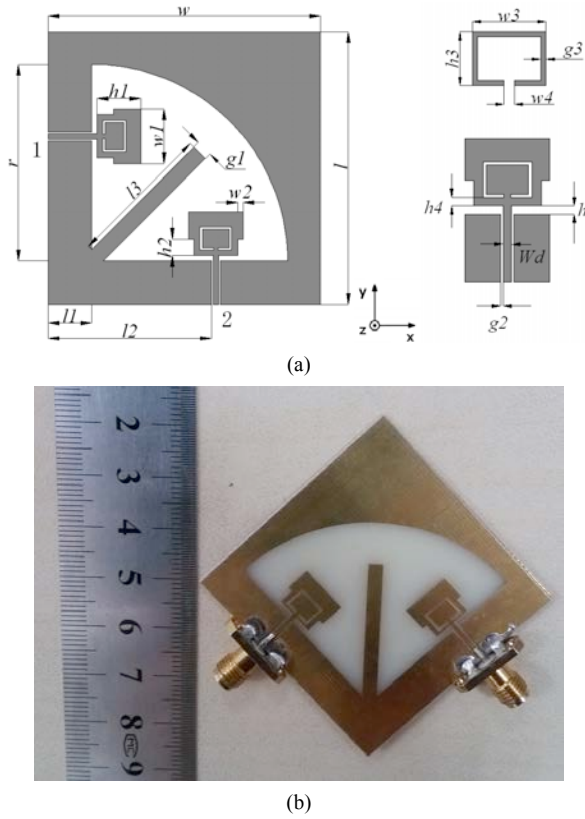


Fig. 17 Proposed antenna geometry. (a) top view and (b) fabricated model view.

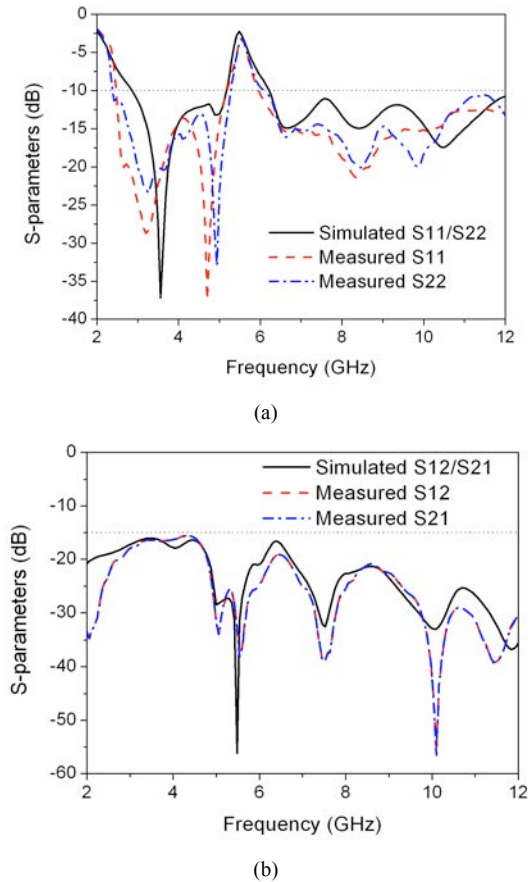


Fig. 18 Measured and simulated S-parameter results of the proposed antenna: (a) S11 and S22, (b) S12 and S21

The bandwidth performance of this proposed antenna is measured by the Agilent E8363B vector network analyzer. Fig. 18 gives the simulated and measured S-parameters of the antenna. As indicated in Fig. 18(a), measured return losses (S_{11} and S_{22}) show some acceptable discrepancies with simulations, due to soldering connectors and fabrication tolerances. Measured results show that this antenna has an impedance bandwidth (return loss ≤ -10 dB) from 2.5-12GHz except for 5.1-6 GHz, which covers UWB standard without WLAN band. The center notched frequency is 5.5GHz, where the return loss is -2.91 dB. Fig. 18(b) and the isolation between radiation ports is more than 15dB through the whole working band (20 dB for most of the band), where the measured results are in very good agreement with calculations.

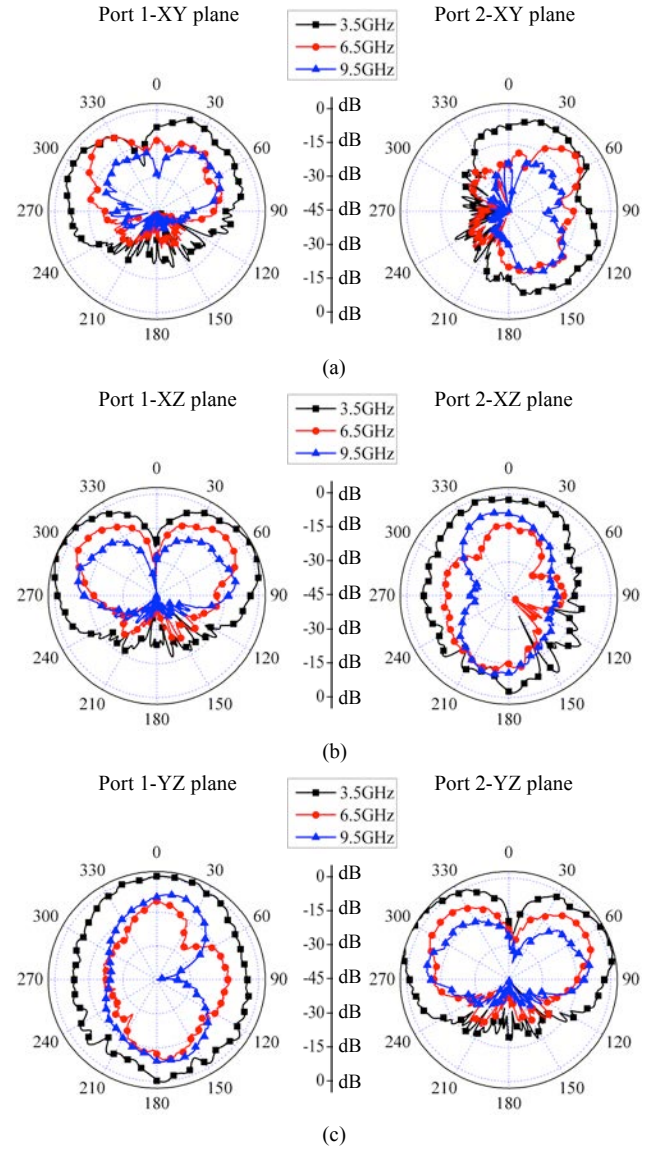


Fig. 19 Measured radiation pattern of the proposed antenna at 3.5, 6.5, 9.5 GHz: (a) XY plane; (b) XZ plane; (c) YZ plane.

Fig. 19 shows the radiation patterns at 3.5, 6.5, and 9.5GHz, when port 1 is excited with port 2 terminated by a 50 Ω load, and vice versa. Due to the symmetry of the structure, the patterns of port 1 and port 2 are rotated 90 degrees. In (a), it is observed in the XY-plane patterns for ports 1 and 2 are almost symmetrical w.r.t. an axis at 45 degrees. In (b) and (c), the radiation of each port is less directional in the H-plane (YZ-plane of port 1 and XZ-plane of port 2) with monopole-like radiation pattern in the E-plane (XZ-plane of port 1 and YZ-plane of port 2). The XZ-plane of port 1 and YZ-plane of port 2 are similar, as for the XZ-plane of port 2 and YZ-plane of port 1. Thus the two ports can radiate a vertically polarized wave and a horizontally polarized wave respectively. The two orthogonal waves have little influence on each other, which weakens the envelope correlation and strengthen the power of the reception. In addition, the computed and measured peak gains of the antenna, from 2 to 12GHz are shown in Fig. 20. For both ports in the working band, the gain is stable with less than 3 dB variation. One sharp decreasing trend is clearly observed at 5.5GHz, which demonstrates that it is effectively notched.

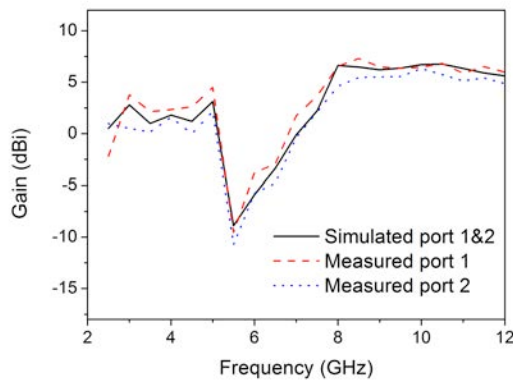


Fig. 20 Peak gains of the antenna.

IV. CONCLUSION

In the paper, our works focusing on the development of compact Ultra Wideband antennas have been presented. In total, four printed UWB antennas, including an ACS-fed CPW antenna for Bluetooth and UWB, a dual band-notched microstrip slot UWB antenna, a fork-like pattern diversity antenna for Bluetooth and UWB with high isolations, and a compact diversity UWB antenna that has band rejection characteristics have been proposed and discussed in detail. Results all show good performance which meet the requirement of relevant standards. In addition, most of them have been greatly reduced in size from the reported ones.

Meanwhile, it is worth mentioning that our group is also working on UWB systems, not only on antennas and transceivers, but also the beam scanning abilities, where we would be more than glad to discuss the development in the future.

ACKNOWLEDGMENT

The authors would like to thank Dr. Antoine Roederer from Delft University of Technology, and Prof. Zhi Ning Chen from the National University of Singapore, for their helpful suggestions. Former graduate students Ling Xiong and Shuang He, current graduate students Yuanfu Liu and Ning Wang are also acknowledged for their contribution to this paper.

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